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by

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A Simulation Study on Take-off and Landing Dynamics of the Aircraft of a Fly-By-Wire Control System

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Abstract
Based on the dynamic theory of rigid body systems combined with the flying kinetic characteristics of aircraft during take-off and landing, a 6-degree of freedom aircraft equation for a rigid body system formed by landing gears-aircraft fuselage is formulated. The pilot time-domain mathematical models for the step-target tracking was proposed, and these models will help evaluate the flying qualities of the pilot/vehicle system during take-off and landing. Then the mechanical control system and the mathematical models for the control-by-wire system are established. The total time-domain simulation procedure of the non-wire type is worked out to provide a complete quantitative analysis of the dynamic qualities in take-off and landing of aircraft, and the results agree well with the flight test data.

Key-words Fly-by-wire-controlled aircraft, pilot model, mechanically controlled aircraft, take-off and landing.

Important Symbols

Fk Total force acting on the k-th rigid body:

mt Mass of the (N+1)th rigid body and (total mass of the airplane);

R The vector of the airplane from the origin of the reference system in the inertial system;

mk Mass of the k-th rigid body;

wo Rotational angular velocity of the axial system of the airplane;

(Rk)o The vector of the k-th rigid body system from the origin in the axial system of the airplane;

rkc The vector of the center-of-mass of the k-th rigid body in the inertial system;

()k relative to the k-th reference system;

wk Rotational angular velocity of the inertial system;

Mo Moment of force of the external force acting on the (N+1)th rigid body with respect to the origin of the axial system of the airplane;

Mko Moment of force of the force vector acted on the k-th rigid body with respect to the origin of the axial system of the airplane;

rc The vector of center-of-mass of the (N+1)th rigid body in the axial system of the airplane;

Ik Moment of inertia of the center-of-mass of the k-th rigid body;

Io Moment of inertia of the (N+1)th rigid body relative to the origin of the axial system of the airplane.

I. Preface

One of the most concerned problems of the designers of aircraft and systems is the dynamic qualities of the take-off and landing (abbreviated as up-and-down) of fly-by-wire aircraft (abbreviated as FBW-aircraft). Because a system can always cause some delay in the reaction of the pilots, and also possess the problems which were not involved at the time of designing, such as all sorts of changes caused by wind shear, any circumstance that require some kind of emergency controls and more often than not would lead to some kind of flight accidents, facing danger to the safety of the passengers and the aircraft, and having to handle a new airplane, all these problems can make and break the research and production. Consequently, the simulation research on the up-and-down dynamical qualities makes a lot of sense.

The habits of a pilot (such as the force of the lever and the range of the lever motion, etc.) to a FBW airplane developed and built in our country is different from that to a machine control system airplane (abbreviated as a MCS-airplane), and the up- and down-characteristics are identical. Thus the processes are the same. If the difference is not too big, the pilot can handle it. On such a basis the purpose of this paper is as follows: (1) Build a dynamical up-and-down model for the combined landing gear - plane fuselage system, to compensate the inertial action of the up-and-down gear which has not been considered and to describe in a simple way the reaction of the ground (1), and because there is a big discrepancy between the mathematical simulation and the actual flight record, by use of the dynamic model proposed in reference (2), the simulation which describes the motions on the ground should be made more accurately; (2) Build a more complete mathematical model of the down-and-up man-machine system, in order to include the motions of the pilot, control system, the up-and-down gear and the motion of the center of mass of the plane, also to involve a non-linear calculation of the air movement and the motion of the plane relative to the ground, etc.; (3) Propose a pilot model for the time domain of the step-target tracking, because in fulfilling the duty of carrying out the landing job and the step-target tracking, there is a big discrepancy between the Neal-Smith standard and the evaluation by the pilot (3). His model was based on the special requirement of the up-and-down process and was obtained after a revision was made on the pilot model of Onstott-Faulkner (3); (4) By use of the non-linear simulation comparison method of the total value time domain to judge the quality of the up-and-down capability of a plane, namely taking into consideration the Neal-Smith standard and the deviation from the accuracy rate of the up-and-down quality expected from the MIL-F-8785C model (5), and also taking any deficiency suggested by the linear system into consideration; (5) Combine all the softwares compiled from the corresponding simulations for various aircraft, to work out the summary quantitative analyses of the dynamic quality in the up-and-down stages, and the results are used to match with the actual flight circumstances.

II. The Airplane Equation for the Combined Rigid-Body of the Up-And-Down Gear - the Fuselage

Hypothesis: The main fuselage of the plane and the active mass of the shock-absorber of the up-and-down gear (the wheels of the plane and the piston cage) can form an ideal rigid body; the outer cylinder of the up-and-down gear is directly connected to the fuselage rigid body.

Ixg-Iyg-Izg is assumed to be the inertial coordinate system. By use of Newton's laws one can derive the dynamic equations. If one can neglect rotation of the earth and the curvature of the ground surface, the ground coordinate system can be assumed to be the inertial coordinate system (see Fig.1);

Ixo-Iyo-Izo is assumed to be the coordinate system of the fuselage. In establishing many rigid body dynamic equations, the common reference coordinate system must be used, and one also has to establish the scalar differential equation from the base up;

Ixk-Iyk-Izk is assumed to be the coordinate system of the down-and-up gear and it is tied to the fuselage, used to establish the equation for the up-and-down gear and to describe its inertial action.

IxR-IyR-IzR is assumed to be the coordinate system of the runway, used to describe the reaction of the ground and the trajectory of the plane;

Fig. 1 shows the entire process of the take-off and landing. The figure shows the above-mentioned coordinate system and its related systems, and in the figure the rigid-body system has (N+1) rigid bodies and subscript "0" is for the fuselage while "k" ($k = 1,\ldots,N$) represents the k-th up-and-down gear.

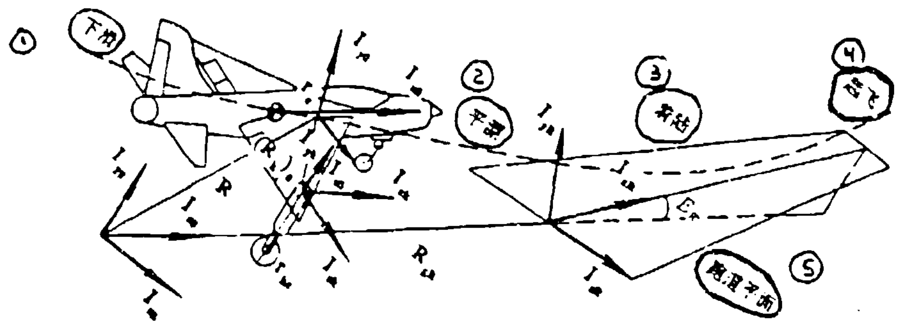

Fig.1 The entire process of the take-off and landing
(1) Sliding down (2) Gliding along (3) landing
(4) Taking off (5) The surface of the runway

1. The total force on the center of mass of a many rigid body system and the total moment of external force

When the external force-vectors are on the (N+1) rigid bodies shown in Fig. 1, while all the internal forces cancel one another out in the process, one gets only the sum of the external forces Fr,

$$\begin{aligned} \boldsymbol{F}_T = \sum_{k=0}^{N} \boldsymbol{F}_k = m_T \ddot{\boldsymbol{R}} + \sum_{k=0}^{N} \{ & (\ddot{\boldsymbol{R}}_k)_0 + 2\boldsymbol{\omega}_0 \times (\dot{\boldsymbol{R}}_k)_0 + \dot{\boldsymbol{\omega}}_0 \times (\boldsymbol{R}_k)_0 + \boldsymbol{\omega}_0 \times [\boldsymbol{\omega}_0 \times (\boldsymbol{R}_k)_0] \\ & + (\ddot{\boldsymbol{r}}_{kc})_k + 2\boldsymbol{\omega}_k \times (\dot{\boldsymbol{r}}_{kc})_k + \dot{\boldsymbol{\omega}}_k \times \boldsymbol{r}_{kc} + \boldsymbol{\omega}_k \times (\boldsymbol{\omega}_k \times \boldsymbol{r}_{kc}) \} m_k \end{aligned} \quad (1)$$

For the same reason, one can get the corresponding total external moment of force

$$\begin{aligned} \boldsymbol{M}_0 = \sum_{k=0}^{N} \boldsymbol{m}_{k0} = m_T \boldsymbol{r}_c \times \ddot{\boldsymbol{R}} + \sum_{k=0}^{N} & m_k [(\boldsymbol{R}_k)_0 + \boldsymbol{r}_{kc}] \\ & \times \{ (\ddot{\boldsymbol{R}}_k)_0 + 2\boldsymbol{\omega}_0 \times (\dot{\boldsymbol{R}}_k)_0 + \dot{\boldsymbol{\omega}}_0 \times (\boldsymbol{R}_k)_0 \\ & + \boldsymbol{\omega}_0 \times [\boldsymbol{\omega}_0 \times (\boldsymbol{R}_k)_0] + (\ddot{\boldsymbol{r}}_{kc})_k + 2\boldsymbol{\omega}_k \times (\dot{\boldsymbol{r}}_{kc})_k + \dot{\boldsymbol{\omega}}_k \times \boldsymbol{r}_{kc} \\ & + \boldsymbol{\omega}_k \times (\boldsymbol{\omega}_k \times \boldsymbol{r}_{kc}) \} + \sum_{k=0}^{N} [\mathbf{I}_k \cdot \dot{\boldsymbol{\omega}}_k + \boldsymbol{\omega}_k \times (\mathbf{I}_k \cdot \boldsymbol{\omega}_k)] \end{aligned} \quad (2)$$

The above 2 equations are complete. However, due to the extreme complication one cannot calculate them and thus some sort of simplication is necessary.

2. Vector dynamic equations for the combined rigid body of the up-and-down gear and fuselage

Combining the special point of the aircraft structure and special proofs for all the up-and-down motions, one can simplify Eqn. (1) and Eqn. (2) to obtain the aircraft dynamic equations with the up-and-down inertial action:

$$F_T = m_T \ddot{R} + \sum_{k=1}^{N} m_k (\ddot{r}_{kc})_k \qquad (3)$$

$$M_0 = I_0 \cdot \dot{\omega}_0 + \omega_0 \times (I \cdot \omega_0) + \sum_{k=1}^{N} m_k ((R_k)_0 + r_{kc}) \times (\ddot{r}_{kc})_k \qquad (4)$$

From the above 2 equations one can write out the corresponding scalar expressions. They can be directly used in any mathematical simulation.

3. Transformation between coordinate systems

From Fig. 1, one sees that in describing the entire process of the up-and-down process, one needs 4 coordinate systems. Between them there exist transformation matrices ; that is, between the runway coordinate system and the inertial coordinate system the transformation matrix

$$\begin{pmatrix} I_{xR} \\ I_{yR} \\ I_{zR} \end{pmatrix} = \begin{pmatrix} \cos E_R & \sin E_K & 0 \\ -\sin E_R & \cos E_R & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} I_{xg} \\ I_{yg} \\ I_{zg} \end{pmatrix} \qquad (5)$$

In the same manner, one can obtain the rest of the transformation matrices.

4. The dynamic equation of the active mass of the up-and-down gear

The shock absorber of the up-and-down gear is a supporter type shock absorber, and considering (Rk)o >> (rkc)k, and neglecting the small coriolis term, one gets the total external force acting on the center of mass of the up-and-down gear and its projection in the motion/ direction, namely SFku, as

$$\sum F_{k_y} = \frac{C_{ok}}{S_{ok} - S_k} + C_k \dot{S}_k |\dot{S}_k| + \mu_{fk} \quad N_{fk} \frac{\dot{S}_k}{|\dot{S}_k|} + F_{Tk} + m_k g \cdot I_{yk} \tag{6}$$

The terms at the right side are respectively the gas compression force, small aperture nodal current resistant force, frictional force of the cylinder wall, ground reaction force and gravitational force. Cok, Sok, Ck and mfk are obtained from the recurrent curves of the static pressure and the landing-shuddering of the up-and-down gear.

5. Explanation of the ground reaction

Usually the ground reaction to the wheels of an airplane can be described by the runway coordinate system, therefore the N pieces of landing gears will receive the ground reactive forces Ffk and their moments of forces Mrk as

$$\boldsymbol{F}_{TR} = \sum_{k=1}^{N} F_{TRk} = F_{TRx} I_{x0} + F_{TRy} I_{y0} + F_{TRz} I_{z0} \tag{7}$$

$$\boldsymbol{M}_{TR} = \sum_{k=1}^{N} M_{TRk} = M_{TRx} I_{x0} + M_{TRy} I_{y0} + M_{TRz} I_{z0} \tag{8}$$

6. Calculation of the compression dk of plane wheels

One can set dk > 0 for the k-th plane wheel grinding along the ground ; dk < 0 when the k-th plane wheel leaves the ground. Thus one can write out the compression of the plane wheel as

$$\delta_k = r_{ok} + y_{ok} + \Sigma(\tau_{Rk}) \tag{9}$$

The terms at the right side are respectively the radius of the plane wheel, the distance from the runway surface to the axis of the wheel, and the ground surface stuffing coefficient.

7. The air characteristics when the plane is in the up-and-down stage

The air characteristics in the up-and-down stage are as follows : (1) Static air motional coefficient is a nonlinear function of the incident angle and the rudder angle; (2) at H < 10 m, the existance of the effect of the ground can vary the air motional coefficients with respect to the altitude; (3) The jet flow at the tail end of the plane can affect the rudder effects when the wheels are making a low velocity upturn.

Consequently, in explaining the air characteristics at the up-and-down stage, the above-mentioned few points have to be considered. Now 2 most commonly used effective numerical methods : multi-dimensional data interpolating method and the multi-term curve asymtotic method. This paper adopts the 2-dimensional smoothed out method of the former kind, because it not only describes the non-linearity accurately but it has a good penetrating power and therefore in solving the nonlinear equations it satisfies the requirement of the control logic solution. From reference (6) one finds the function of the 2-dimensional smoothed out shape line as

$$S(x,y)=\sum_{k,l=1}^{4} a_{ijkl}(x-x_i)^{k-1}(y-y_j)^{l-1} \tag{10}$$

In the formula the matrix { } can be found in the initial simplifying process before the simulation, and it can be directly used in the dynamic solutions to increase the transport velocity.

When the above 2 expressions are inserted into equations (3) and (4), one can solve the dynamic equations of the combined rigid body of the up-and-down gear - fuselage.

III. Step-Target Tracking Pilot Model

Early in 1970, Neal and Smith suggested the Neal-Smith standard for the problem of target-tracking in trailing a plane and as the pilot model there is McRuer's almost linear model, to evaluate the flight quality at the frequency region. In 1978, Onstott and Faulkner made a further analysis on their experimental data to point out that at the time of step-target tracking the difference between their standard and the evaluation by the pilot was too great (4), and consequently the step-target tracking pilot model had to

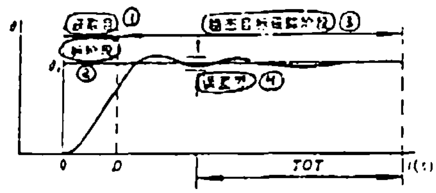

Fig.2 The Step-Target Tracking Pilot Model
(1) Target to be attained (2) Stage being shown
(3) The tracking stage for the Target of Hidden Shape
(4) Error Band

After the step-target has appeared, the pilot has to control the plane in catching the target. When the plane is close to the target, the pilot goes into operation to track down the hidden shape. Any experienced pilot can let the attitude make excessive response to cut the time short for the taking-off process and the adjustment to be made is also small. In actuality, the operation by such pilots comes near to the "bang-bang control" (4).

From the above analysis, Onstott and Faulkner suggested the step-target pilot model to let the pilot make a flat-tail operation in 2 stages, namely to catch the target and to track down the hidden shape, as shown in Fig. 2. In the figure, D is the time when I = 80 % of Ic ; TOT is the time required to respond in getting into the error range.

The step-target tracking pilot mathematical model (4) shows that

$$\left.\begin{aligned}\delta_{cl} &= (\text{Delay}\tau) k_{pl} [\vartheta_e(t) + T_{Ll}\dot{\vartheta}_e(t)], \quad 0 < t < D \\ \delta_{cF} &= (\text{Delay}\tau)\, k_{pF} \left[\vartheta_e(t) + T_{LF}\dot{\vartheta}_e(t) + k_{IC}\int_0^t \vartheta_e(t) pt\right], \quad D < t < T\end{aligned}\right\} \quad (11)$$

In the formula dcl and dcF are, respectively, the amounts of control at the flat-tail posture in 2 different stages; t is the delayed time on the part of the pilot in his operation, usually in the range of 0.15 - 0.3 s ; kpl, kpR, kIC and TLI, TLF are, respectively, coefficients and time-constants, and to get the right dipping angle in the shortest possible time one has to improve such coefficients to the perfection in order to attain good flying quality evaluation.

After Onstott and Faulkner compared TOT and RMS (root mean square error) with the evaluation by the piot, they proposed the evaluation standard for the step-leap tracking quality (4) to overcome the fairly large deficiency existing in the Neal-Smith standard.

By use of the time domain step-target tracking model, one can use it in the study of a nonlinear system, or in a large scale control. Such salient features can be utilized in describing the up-and-down operations. From the rules for pilots (7), one can see that the taking-off controlling devices have a special capability to track down the step-target. Upon lifting off from the runway the pilot controls the plane to catch the proper angle of inclination to make a straight dash into the sky, maintaining the same attitude.

One has to consider how much the rudder angle is needed to lift the front wheels in keeping pace with the speeding up and reducing the surface speed of the plane. Now if all the coefficients in formula (11) are some fixed numbers, they cannot satisfy all the different speeds of the gear-wheels, while the responding attitude cannot surpass the required angle of inclination. Consequently, the present authors try to make some revision to the pilot model so that by inserting into the model the inclination angle ac (=Ic) required in making a lift-off from the runway and the rudder's static tilting angle do (v) needed for the 2 wheels to make smooth taxing, in order to satisfy the nonlinear characteristics of the taking-off operation, the formula (11) should be revised to be

$$\left.\begin{aligned} \delta_{el} &= \mathrm{Delay}\,\tau\{\delta_0(v) + k_{pl}[\vartheta_e(t) + T_{Ll}\dot{\vartheta}_e(t)]\}, \quad 0<t<D \\ \delta_{eF} &= \mathrm{Delay}\,\tau\left\{\delta_0(v) + k_{pF}\left[\vartheta_e(t) + T_{LF}\dot{\vartheta}_e(t) + k_{Ic}\int_0^t \vartheta_e(t)dt\right]\right\}, \quad D<t<T \end{aligned}\right\} \qquad (12)$$

In the formula, do(v) can be found by solving the static equilibrium equation for the airplane control. The revised model can control planes at any surface speed during an automatic take-off.

From reference (8), one can see that in the process for a plane to slide down, glide to horizontal posture, touch down and tax along, the pilot tends to overcontrol during the stage of sliding down and gliding to straight posture, and can create the phenomenon of pilot-induced oscillation (abbreviated as PIO). At this junction the pilot can feel them out by himself or the instruments can promtly take care of the attitude (I, I) and the sinking rate (dH/dt). They are all affected by the trajectory of the plane, and the trajectory can overstep the inclined wheels of the rudder-blade and press them down hard (for ordinary airplanes) Thus most pilots rise the amount of operation, needed to make a landing, as an important factor in his control. In such case, one can use the above-mentioned model, but the coefficients in the formulas need the appropriate revisions.

IV. Esample of Computation and Analysis of the Results

This paper combines the Fortran-77 language used in various aircraft to compile software for mathematical simulations. It has an easy and powerful versatility to analyze each stage of the motions of the MCS- and FBW-aircraft and to evaluate their qualities.

1. Evaluation of the quality of the take-off functions of MCS- and FBW-aircraft

The evaluation method utilizes the same operational logic to find out the difference in the MCS and FBW type, and by using the same kind of aircraft, it can obtain their corresponding dynamical responses. First, by comparing the former with a test-flight curve to check the accuracy of the mathematical model. Then comparing and analyzing the dynamical response of the MCS- and FBW-plane to determine the quality of the latter.

Fig. 3 shows the dynamical responses of the inclination angle in MCS- and FBW-plane, obtained at v = 260 km/h for the front wheels and under the conditions of the same pilot model coefficents.

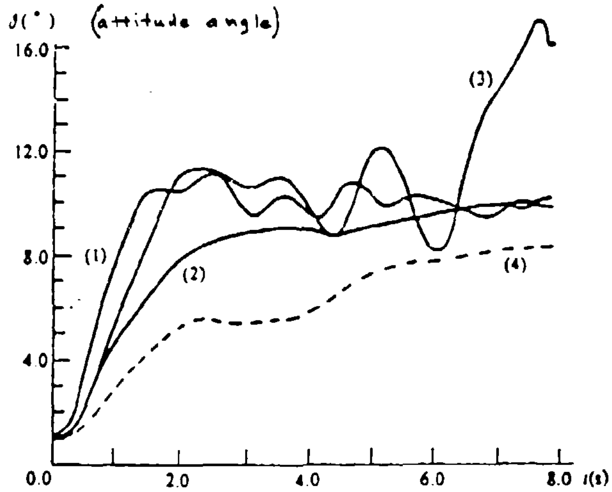

Fig.3 The Dynamical Response of the Inclining Angle of MCS- and FBW-Airplane
(1) -MCS Airplane; (2) -FBW Airplane (XG=37%); (3) -FBW Air-Plane (XG=42%); (4) -Test Flight Curve (MCS Airplane)

From Fig.3, one sees the following items : The test flight curve and simulation response (1) had the same rules of changing, and the main difference was the smoothness in the operational activities of the pilots and thus there was no oscillation phenomenon. In going through the coefficients of surpass-adjusting equation (12), by lowering kpl and TLF one can make these two agree with each other. Consequently, it shows that the mathematical model established in this paper is accurate and is reliable; (2) and (3) in the figure are showing the dynamical responses of the FBW-planes; responses in (2) and the MCS-plane were identical and thus the function satisfied the required quality, but responses in (3) let vibrations get out of hand, and they were the typical PIO phenomena. Moreover, at the initial stage the time-delay was also relatively large.

The reason of inducing the PIO phenomena is as follows:

(1) The pilot received too much of the increment values; (2) in the mathematical form of FBW, there was a relatively large system time delay. By reducing the increment values, smooth operational activities would ensue and are capable of eliminating the PIO phenomena, but unfortunately at the same time it lowers rapidity in response (as in (2) of the figure). From this fact one can see that soft operational activity can stay away from large inclination angles right before the plane is making a lift-off from the runway regardless of the surface speed, and thus it can reduce the taxiing distance for take-off.

2. Simulation of Landing Dynamics

A mathematical simulation can also be carried out on the ordinary landing and taxing process, such as sliding down, gliding flat, touching down and then landing. The simulation results show that the combined dynamic equation can give a unified quantitative description of the ground reaction force (see Fig. 4), dynamics of the up-and-down gear, the rate of decrease of the center of mass of the plane, and the response of the angle of inclination, areshown in Fig. 5.

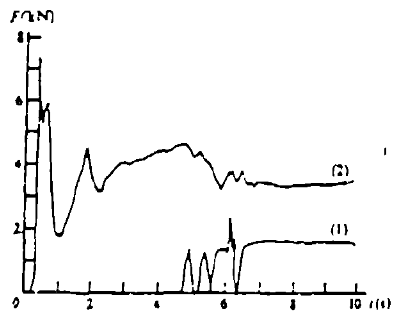

Fig. 4 The ground reaction force perpendicular to the plane wheel
(1) - front wheels (2) - the main wheel

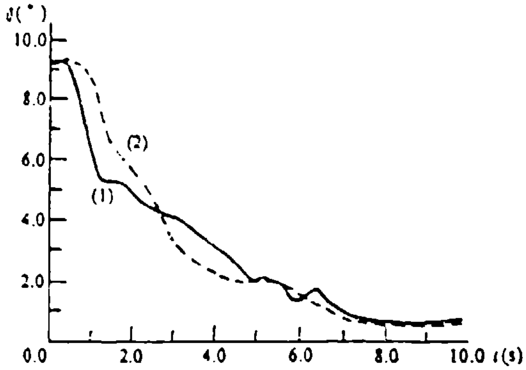

Fig. 5 Dynamical response of the angle of inclination
(1) -FBW airplane (SG = 37 %)
(2) -Test Flight Curve (MCS Airplane)

V. Conclusion

The results of computation clarify the following ite.. : In considering dynamics of the up-and-down gear and the nonlinearity of the gas movement, there is agreement between the simulation on dynamics of the up-and-down gear of the plane and the actual flight situation. Thus it explains that the model established in this paper is reliable and accurate. Therefore one can use it to evaluate and inspect the up-and-down characteristics, it also exposes the fact that the plane with the human pilot cannot carry out the dynamic functions assigned to men, and at the same time can help designers recognize and improve the control system functions of the plane.

Also by revising and expanding the simulation procedures one can broaden the area of application to some related fields of research to carry the study to the loading problem of the up-and-down gear, to simulate the breaking down in the up-and-down process for various kinds of aircraft (such as civilian airliners and weather watching aircraft, etc.), to do research on cargo planes and on the up-and-down technology for the short-runway up-and-down techniques or even the vertical up-and-down techniques, and to study dynamic characteristics, etc. of the combined man-machine closed system.

Reference

1. Zhinyen Zhiu, Feng-Zhin Shee, and Enmo Yu : Simulation of Motion of a Plane on a Surface, Fly Mechanics, 1985; (2).

2. AFFDL-TR-71-155, Takeoff and Landing Analysis (TOLA) Computer Program, Part I, II, III, IV.

3. USAF. AFFDL-TR-65-15, 1985.

4. Onstott, E. D., Discrete Maneuver Flying Qualities Consideration in Control system Design, IEEE, 1985.

5. Martz, J. J., Bizadt, D. J., Didominico, E. D., Loop Separation Parameter: A new Metric for Landing Flying Qualities, Journal of Guidance, Control and Dynamcis, 1988; 11, (6).

6. Ed. by Tekue Liu, et al., The Fortran Computation Method First Volume, National Defence Technology Publishing Co., 1984.

7. Rules for Flight Attendants and Pilots, Chinese Peoples' Liberation Aircorp General Command, 1986.

8. Anderson, M. R., Schmidt D. K., Closed-Loop Pilot Vehicle Analysis of the Approach and Landing Task, Journal of Guidance, Control and Dynamics, 1987; 10 (2).

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